AD 46301

UNCLASSIFIED

THE OKONITE COMPANY

LOW NOISE, HIGH POWER PULSE CABLE

QUARTERLY REPORT #5

FEBRUARY 15, 1954 to MAY 15, 1954

S.C. CONTRACT DA 36-039 SC 42669

HIGH POWER, NOISE FREE PULSE CABLE

FIFTH QUARTERLY REPORT

CONTRACT NO.	DA-36-039 SC 42669
FILE NO.	13259-PH-53-91(3403)
DEPT. OF ARMY PROJECT NO.	3-26-00-602
SIGNAL CORPS PROJECT NO.	2006C

PLACED BY: U.S. ARMY SIGNAL
CORPS LABORATORIES
FORT MONMOUTH, N.J.

THE OKONITE COMPANY

PASSAIC, NEW JERSEY

HIGH POWER, NOISE FREE PULSE CABLE

FIFTH QUARTERLY REPORT

FEBRUARY 15,1954 to MAY 15, 1954

I. OBJECT

To design ahd manufacture pulse cables of 50, 25 and 12-1/2 ohms capable of handling from 5 to 40 megawatts of peak pulse power with a minimum of radiated noise and capable of operating over an ambient temperature range of 55°C to -55°C with a maximum hot-spot cable temperature of 125°C.

CONTRACT NO.	DA 36-039 SC 42669
FILE NO.	13259-PH-53-91(3403)
DEPT. OF ARMY PROJECT NO.	3-26-00-602
SIGNAL CORPS PROJECT NO.	2006C

PREPARED BY: ROBERT G. FELLER

APPROVED BY: F. H. GOODING

HIGH POWER, NOISE FREE PULSE CABLE

FOURTH QUARTERLY REPORT

III. TABLE OF CONTENTS

	PAGE
I. Object	a
II. Table of Contents	b
III. Purpose	c
IV. Abstract	1
V. Conferences	2
VI. Factual Data	3
A. Interchemical Butyl Compound 1354	3
1. General	3
2. Cable Design	3
3. Test Results	3
4. Recheck of Slabs	4
B. Type 2515 Cable	4
1. General	4
2. Improved Design	5
C. Type 1215 Cable	5
1. General	5
2. Electrical Tests	5
D. Type 1230	5
1. General	5
2. Design	6
3. Calculated Electrical Properties	6
4. Calculated Thermal Properties	6
5. Weighted Attenuation	7
6. Power Rating	7

TABLE OF CONTENTS
(cont'd)

	PAGE
E. Shielding	8
1. General	8
2. Transfer Impedance	8
3. Screened Cage	8
4. Method of Pickup	9
5. Test Procedure	9
1. Single Braided Cable	10
2. Solid Copper Tubing	10
6. Difficulties Encountered with Interlayer in Triaxial Shielded Cables	10
1. General	10
2. Design #1	11
3. Design #2	11
4. Present Design	11
VII. Conclusions	12
VIII. Program for Next Interval	13
IX. Time Record	14
X. References	15
XI. Curves	

Figure 1(5) - Attenuation vs Frequency. Type 2515 cable (1) with Interchemical 1354 Butyl Compound (2) with 022349A Butyl Compd.

Figure 2(5) - Power Factor vs Frequency Cable Type 2515 (1) with Interchemical 1354 compound (2) with Okonite 022349A compound

FIGURE 3(5) - Dielectric Constant vs Frequency Type 2515 cable with Interchemical 1354 Compd.

TABLE OF CONTENTS
(cont'd)

XI. CURVES. (cont'd)

Figure 4(5) - Table Weighted Attenuation Type 2515BI Silicone Cable.

Figure 5(5) - Shielded Cage Setup for Measuring Shielding Effectiveness

Figure 6(5) - Shielding Effectiveness Measurement Circuit #1.

III. PURPOSE

To provide services, facilities and materials to conduct development leading to the establishing of designs for pulse cables, capable of handling high peak power and exhibiting low noise radiation, and also, the fabrication of samples for component testing purposes.

This period has been devoted to the design and fabrication of types 1215 and 1230 cables. Type 1215 being a 12-1/2 ohm, 15 KVP cable capable of handling 20 megawatts of peak pulse power and type 1230 being a 12-1/2 ohm 30 KVP cable capable of handling 40 megawatts of peak pulse power.

IV. ABSTRACT

Type 2515 cable has been fabricated with Interchemical 1354 compound. The electrical tests show little, if any improvement over the 022349A compound. The compound was a rather dry compound and we had difficulty in extruding the material. We are marking slabs of this compound here at Okonite to compare with slabs submitted by Interchemical Corporation.

We have made a calculation on type 1230 cable using Silicone rubber. Calculations show that a cable of this construction would generate at a .002 duty cycle and a 0.3 microsecond pulse satisfactorily if the 30 KVP corona extinction could be met and a suitable semiconducting material could be found.

The study of shielding using a screen covered cylinder has been started. The pickup is more than sufficient using a tuned antenna and feeding that signal into a radio receiver and then into a wave analyzer.

We have encountered difficulty in the comparison of a single braid cable and a cable using a 1/8" copper tube as a return circuit. The cable with the copper tube appears to radiate more than the cable with the single braid. This does not check according to theory. We are investigating this at the present time.

Difficulty has been encountered with the intermediate shield puncturing the insulating interlayers. A design using teflon tapes over the two mild steel tapes and then silicone rubber glass tapes has been used satisfactorily and a construction of this nature will be used on the cables in the contract.

V. CONFERENCES

May 5, 1954 - Meeting held at Squier Laboratories, Fort Monmouth, N.J. Present were Messrs. Spergel, Tenzer and Shive of the Signal Corps. Messrs. Feller and Gooding of the Okonite Company.

A discussion concerning the measurement of leakage through the shielding was held. The transfer impedance method was discussed. It was concluded that this method, due to lack of a high frequency power supply was good up to 3 or 4 megacycles at the most. As the frequency increases the length of cable under tests becomes an appreciable part of a wave length and difficulties are encountered.

It was decided to build a shielded cylinder through which the cable under test would pass. A signal generator would be attached to one end and a shielded load to the other end. The signal would be picked up by a tuned loop antenna located inside the shielded cage.

By substituting various types of shielded cables it is hoped that effectiveness of the various types of shieldings can be compared.

The construction of type 5015 cable was under consideration. The size and flexibility are major problems.

VI. FACTUAL DATA

A. Interchemical Butyl Compound 1354

1. General

A cable has been designed and fabricated using type 1354 Butyl compound furnished by Interchemical Corporation. This compound contains a percentage of polyethylene, which contributes to lowering the power factor. The reason for choosing this particular compound was that it exhibited a power factor that was relatively lower than any other Butyl compound tested. (See Quarterly Report Number One, Figure 10(1).

2. Cable Design

Using the above compound we have designed a cable of type 2515 using the same core as used in type 2515 BI cable. A layer of semiconducting butyl was extruded over the braided inner conductor and the 1354 insulating butyl extruded over the semiconducting butyl. This compound was quite dry and was rather hard to extrude. The cable, after curing in a pan, was rather rough and grainy on the surface. Instead of going ahead as planned in the experimental order we decided not to apply a semiconducting layer over the insulation and applied the 48 carrier , 9 ends tinned copper braid overall. We, then tested the cable to determine the electrical properties.

3 . Test Results

The test results on eighty-five feet of cable show little if any reduction in attenuation over the cable made with 022349A Butyl compound.

In Figure 1(5) the attenuation vs frequency is shown for the cable with 1354 compound and also for type 2515AI-B, a butyl cable which was made of 022349A Butyl with no semi-conducting compound over the inner conductor.

In Figure 2(5) the power factor vs frequency shows a slightly lower power factor than type 2515AI-B. This is expected since the cable with 1354 compound has no semi-conducting compound over the insulation. It is felt that the presence of this would raise the power factor to a position equal to the type 2515 cable with the semiconducting butyl over the insulation.

Figure 3(5) shows the dielectric constant over the frequency range of 0.5 mc to 5.0 megacycles. This value, compared to the slab tests is appreciably higher. This again points out the inconsistency in the correlation between slab and cable tests.

4. <u>Recheck on Slabs</u>

To determine if the higher than expected power factor was due to the method of compounding at Passaic or to the working that the material received while tubing we are making some slabs for comparison with the slabs supplied by Interchemical Corporation here at Passaic.

B. <u>Type 2515 Cable for Contract Requirement</u>

1. <u>General</u>

This cable is a 25 ohm cable rated at 15KVP and should be capable of handling 10 megawatts of peak pulse power. This cable has been completed. The design submitted to the Signal Corps for tests uses a steel braid as the intermediate shield and is of triaxial construction. We have encountered some difficulties with this type of shield construction. The braid ends puncture the insulating interlayer between shields thereby causing a short circuit between the outer two braids. We are working on an improved design at present using steel tapes in place of the braids. This type of shielding has been used on type 1215 cable.

2. Improved Design

We are preparing another experimental order on this type of cable withthe following improvements in mind:

1) to decrease the bond between the insulation and the semi-conducting compound for easier stripping.
2) to raise the impedance of the cable slightly to 25 ohms
3) to use an improved shielding design to prevent short circuits between shields and to give good electrical shielding.

The final step will be held pending the present investigating being made on the effectiveness of different types of shieldings and the efficiency of various types of interlayers.

C. Type 1215 Cable

1. General

We have completed a sample length of 1215 type cable. This is the 12-1/2 ohm, 15KVP 20 megawatt cable using an aluminum tube as a hollow core. As mentioned before this cable has been shielded using two mild steel tapes in place of the steel braids as the intermediate shield under the interlayer of silicone rubber glass tapes. (See Fourth Quarterly Report Figure 9(4) for drawing).

2. Electrical Tests

The elctrical tests have to be made on this cable and should be completed very shortly.

D. Type 1230

1. General

Some preliminary calculations have been made on this type of cable. The specification requires a 12-1/2 ohm 30 KVP cable capable of handling 40 megawatts.

2. Design

Using aluminum tubing similar to that used on type 1215 cable and silicone rubber as the insulation we find the following information from calculations.

3. Calculated Electrical Properties.

Using a 7/8" dia. aluminum core covered with a .010" tinned copper braid for an inner conductor, then a semi-conducting layer, .250" of silicone rubber DC80, a semiconducting layer and a .010" tinned copper braid we obtain the following approximate figures.

Z = 12.7 ohms

C = 137 uufd/ft.

L = 23.4 uh/1000 ft.

R_{ac} = .281 ohms/100 ft. at 1 mc.

= .487 ohms/100 ft. at 3 mc.

α = .1084 db/100 ft. att. at 1 mc.

α = .2074 db/100 ft. att. at 3 mc.

The above attenuation figures correspond quite closely to the values obtained on type 2515BI cable made with silicone rubber.

4. Calculated Thermal Properties

Calculating the thermal resistance of this cable.

R surface to air	=	2.05 th-ohms
R insulation	=	.40 th-ohms
R total	=	2.45 th-ohms

This figure does not include the jacket thermal resistance or the resistance of the interlayer.

The watts/ft dissipation.

$$W = \frac{\Delta T}{R_{th}} \text{ watt/ft} \quad \text{where } \Delta T = \text{temperature difference between condr. and ambient} = 125°C - 55°C = 70°C$$

R_{th} = total thermal ohms

$$W = \frac{70}{2.45}$$

$$= 28.6 \text{ watts/ft}$$

5. Weighted Attenuation

Using the attenuation formula and the weighted attenuation on type 2515BI cable to obtain an estimate of the losses that may be expected in the 1230 cable, we obtain

α = .267 db/100 ft. weighted attenuation on 2515BI cable with 0.1 usec pulse. See Figure 4(5).

6. Power Rating

$$\alpha = 10 \log_{10} \frac{P_1}{P_2} \text{ db/100 ft.}$$

and $P_1 - P_2$ = 2860 watts/100 ft. loss

$$P_1 = \frac{P_1 - P_2}{1 - \frac{1}{\text{antilog} \frac{\alpha}{10}}}$$

$$P_2 = \frac{2860}{1 - \frac{1}{1.062}}$$

$$P_2 = \frac{2860}{1 - .94}$$

$$= \frac{2860}{.06}$$

$$= 47{,}700 \text{ watts maximum dissipation}$$

Using a .002 Duty cycle the

$$\text{Av. Power Rating} = \text{Duty Cycle} \times \text{Peak Power}$$
$$= .002 \times 40 \times 10^6$$
$$= 80{,}000 \text{ watts}$$

As a rough calculation this cable would operate at a .002 duty cycle and a pulse width of .2 usec according to the above calculations assuming the maximum power dissipation to be proportioned to the pulse width as shown in the butyl rubber cable calculations. (See Quarterly Report No. Four)

E. Shielding

1. General

One phase of the contract is to provide the best possible shielding for the pulse cables fabricated during this contract. We have reached the stage where it is necessary to study various shield constructions and the best type of insulating interlayer.
The effect of the thickness of the interlayer if any, upon the overall shielding is to be studied.

Some means is necessary to measure the relative effectiveness of the different shielding constructions. We are planning to compare a single, a double and a triple braided cable and also the triaxial type shielded cable.

2. Transfer Impedance

One method of measuring the effectiveness of a shielded cable is by Transfer Impedance. With the existing equipment and experience on Signal Corps Contract DA 36-039 SC 42649 it does not appear possible to make these measurements at a frequency higher than 3 megacycles.

3. Screened Cage

Another method which may give a wider range of frequencies is being investigated. We are using what amounts to a small screened room in the form of a cylinder covered on the inside with fine mesh bronze screen. The cable is suspended through the center of this cylinder and held in place inside a 2" plastic tube.

The power is supplied by a pulse generator borrowed from the Signal Corps. This unit is well shielded and the pulse circuit can be isolated from ground. The unit will produce a 1 microsecond pulse or a 0.5 microsecond pulse with a peak voltage of approximately 5000 volts at a repetition rate of 500 cycles per second.

The load is composed of suitable non-inductive resistors to make up 50 ohms and also is shielded and can be isolated from ground.

The three units, the generator, the screened cage andthe load are located very close together as can be seen in Figure 5(5).

The screened cage itself is six feet long and has a 30 inch inside dimension. We have made ports around the cage to insert the probe or antenna to check the uniformity of the field. When the ports are not being used they are covered with a copper plate.

4. Method of Pickup

A tuned coil antenna is being used as the pickup. The signal is being fed into a Signal Corps Radio Receiver Model BC 348P. The output of the receiver is fed into the Hewlett Packard Wave Analyzer Model 300A. A very substantial signal is obtained in this manner in the range of several thousand millivolts. All pickup leads are triple shielded to reduce any stray pickup.

5. Test Procedure

Preliminary tests have been made using a single braided cable and also a cable covered by a copper tube approximately 1/8" thick.

1. Single Braided Cable

Figure 5(5) shows the test circuit used to measure the leakage through the braid. The receiver was set at 2.0 mc and the wave analyzer to 500 cycles. A 1 microsecond pulse was used. The output of the receiver was adjusted to give a reading of 3000 millivolts on the analyzer with a input of 1200 volts peak.

The antenna was used as a probe and it was found that the radiation was uniform around the cable and that it increased as the antenna was brought nearer to the cable. The ends of the cage were probed and no appreciable leakage could be detected or any change in the field inside the cage.

2. Solid Copper Tubing

The single braided cable was then replaced by the same cable, minus the braid but using a 2" copper tube as the return circuit instead of the braid. The antenna and dial settings remained in the same position as in test #1.

The pickup was 5000 millivolts. This value was carefully checked with the same result. It would seem that the attenuation due to the copper tubing should be much less than that of a single braid. As a check the next step is to test the two samples without the shielded cage to see if reflections have any effect on the increase in readings with the copper tubing. The above results were at only one frequency. Reflections from the cage itself will be studied to try to account for these anomalies.

6. Difficulties Encountered with Interlayer in Triaxial Shielded Cables

1. General

In previous experiments and also on production orders in the factory we have been using two ten mil Silicone rubber glass tapes as the interlayer.

2. Design One

However, we have found that when using a steel braid as the intermediate shield under these tapes the ends of the steel braid tend to puncture the tapes, thereby causing a short circuit when flexed.

3. Design Two

We then went to a construction similar to that used on type 1215 cable using two steel layers in place of the steel braid. However we encountered difficulties with this construction also. The spacing between the steel tapes was not sufficient to allow bending. The tapes would butt together and when bent further would buckle at the edges, thereby producing a sharp point and piercing the interlayer.

4. Present Design

The present design uses the two steel tapes, with a wider negative lap to permit a suitable bending diameter, and covered with two teflon tapes as an increase in the dielectric properties of the interlayer and also as a protection to the glass tapes. The teflon tape is much stronger mechanically than the glass tape. Different types of interlayer materials are being investigated. The problem involved is getting a suitable material that will be flexible at -55°C and that also is strong physically as well as electrically.

VII. CONCLUSION

1. From electrical tests on type 2515 cable made with Interchemical 1354 compound we would conclude that this compound is no better than the 022349A compound in power factor.

2. The Interchemical 1354 compound will be rechecked on slabs.

3. If a semiconducting compound can be found for Silicone rubber which would be corona free at 30 KVP a cable could be fabricated which would operate at a .002 duty cycle and a 0.2 usec pulse.

4. A steel braid as the intermediate shield is not advisable due to the ends puncturing the insulating interlayer and causing short circuits.

5. The transfer impedance method is not suitable for measuring the effectiveness of shielding.

6. The screened cage appears to be suitable for radiation measurements in preliminary tests.

7. More work has to be done on the type of interlayer to be used on the cables.

VIII. PROGRAM FOR NEXT INTERVAL

1. Check Interchemical 1354 Butyl compound made at Passaic with original slabs made at Interchemical.

2. Try to reduce bond between semiconducting Butyl and Butyl insulation.

3. Write and enter experimental order for type 2515 cable with revisions to raise impedance slightly and decrease bond between butyl insulation and semiconducting compound. Also to use steel tapes in place of steel braids as intermediate shield.

4. Write and enter experimental order to obtain length of type 1215 for test purposes and to iron out production difficulties.

5. Work on design of type 1230 cable.

6. Study effectiveness of shielding and affect of different interlayers on shielding properties with screened cage that is now available.

7. Investigate use of various materials as interlayer in connection with (5) above.

8. Enter experimental order on type 5015 cable using butyl insulation.

9. Investigate another lightweight material for hollow core in type 1215 and 1230 cables which would be mechanically stronger.

10. Make flexibility test.

11. Measure corona while flexing.

12. Measure impulse level of completed cables.

IX. TIME SPENT TO DATE ON CONTRACT

NAMES	HOURS
F. H. Gooding	378
H. B. Slade	31
R. G. Feller	1,071
Laboratory Tech.	550

IX. REFERENCES

1. Signal Corps Contract DA 36-039 SC 42649
   Multi-Pipe Coaxial Cable

2. Signal Corps Contract DA 36-039 SC 42669
   High Power, Low Noise Pulse Cable
   Quarterly Reports 1, 2, 3, 4

ATTENUATION VS FREQUENCY
TYPE 2515
FABRICATED CABLES

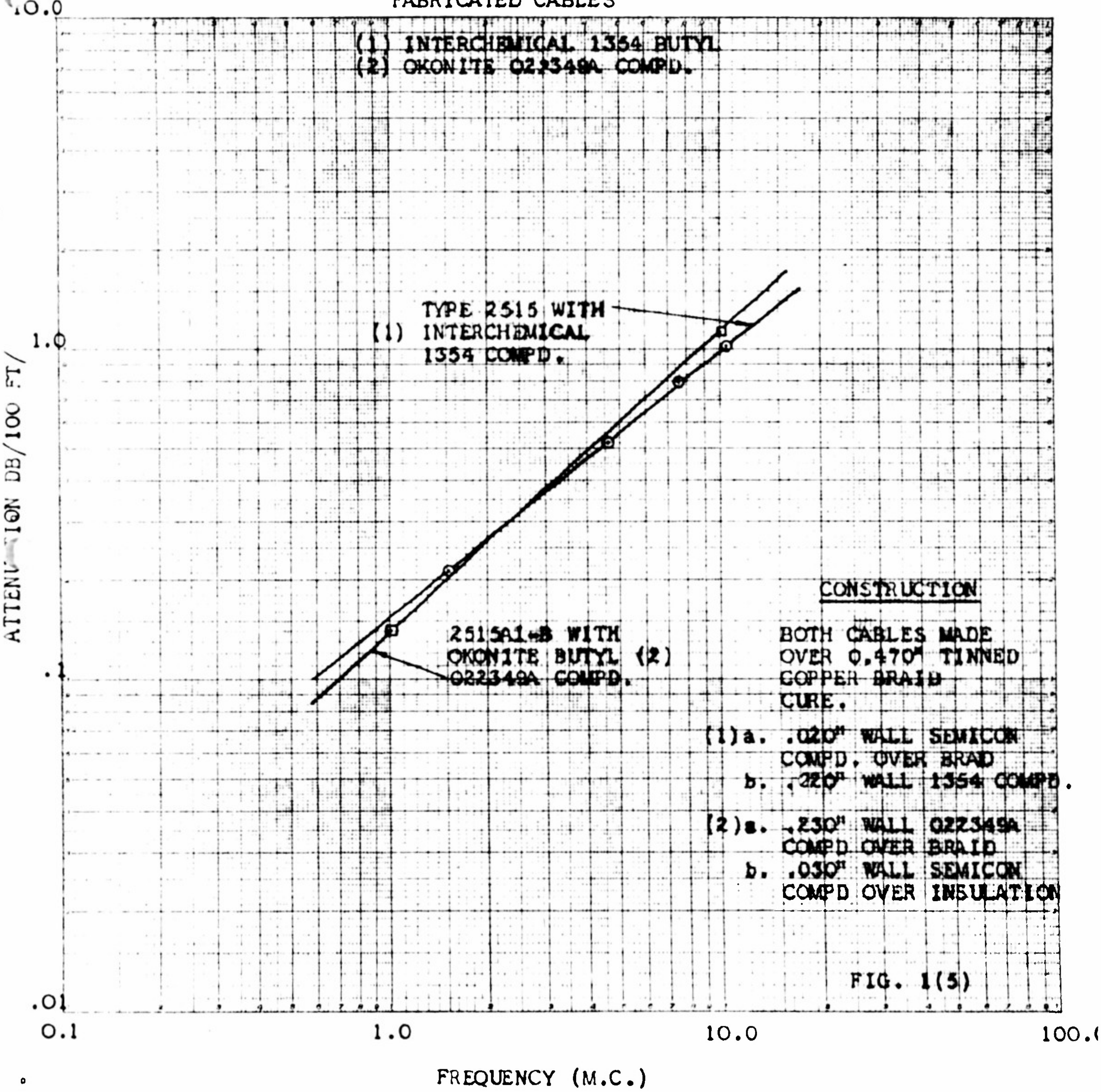


FIG. 1(5)

POWER FACTOR VS FREQUENCY

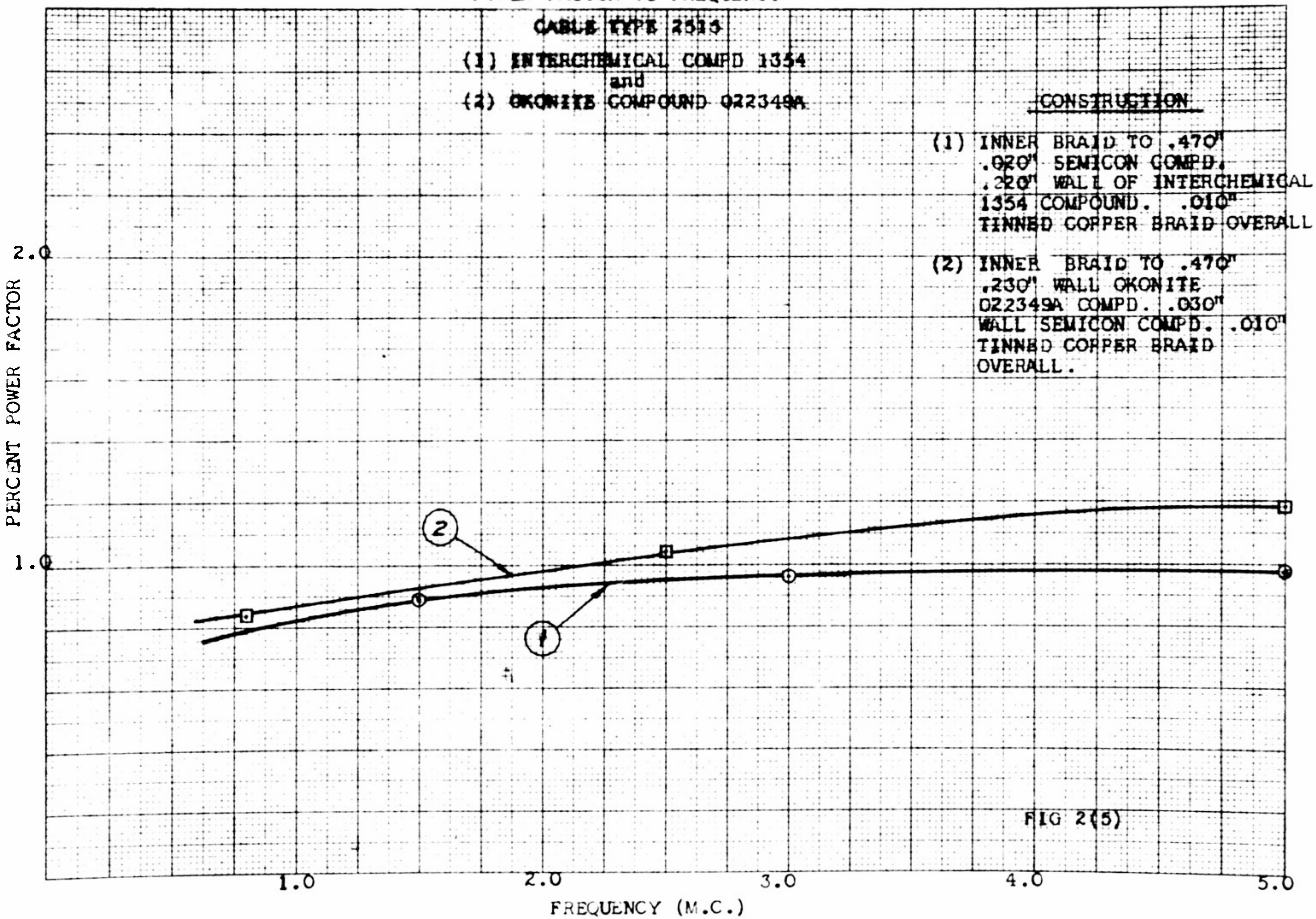


FIG 2(5)

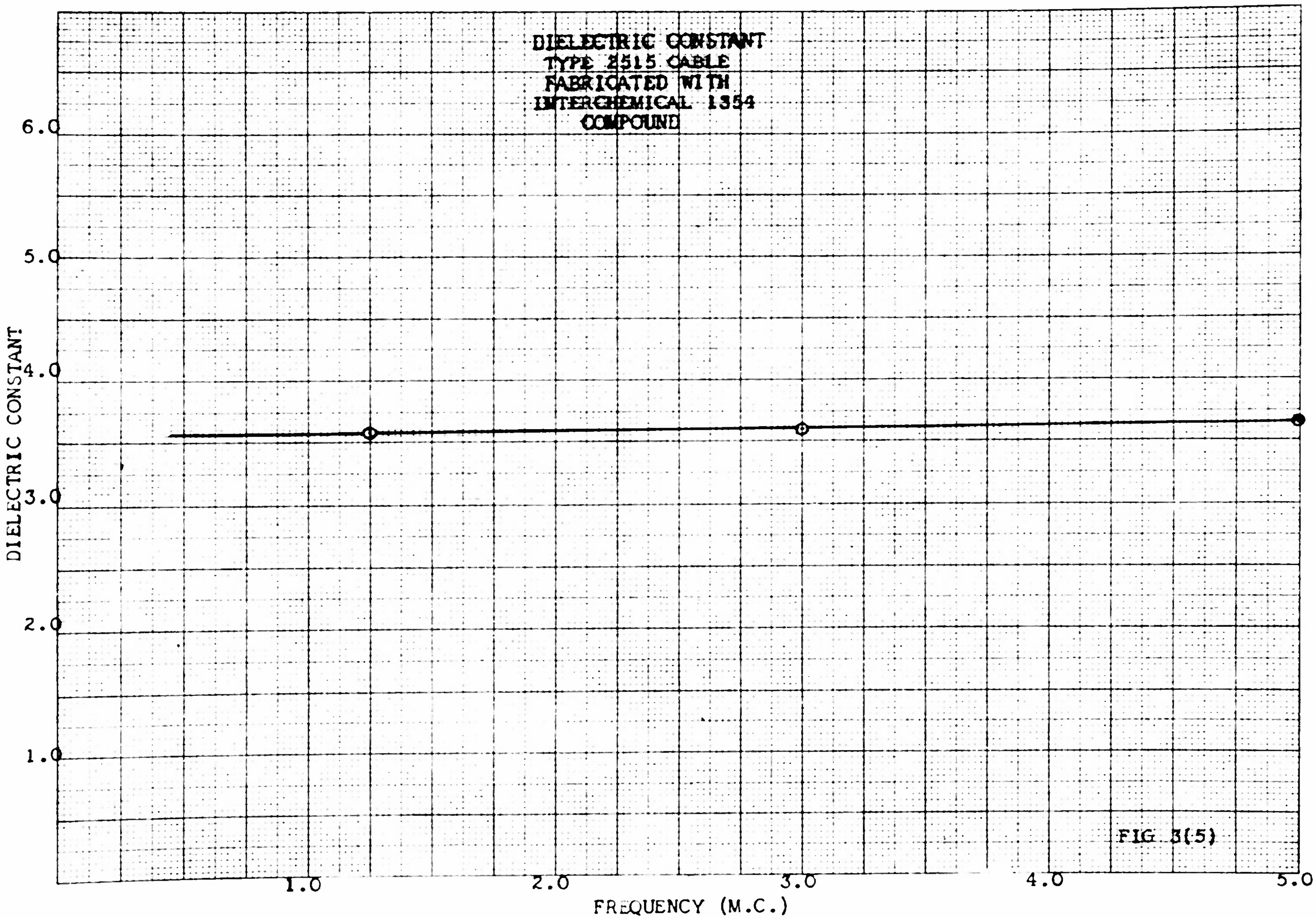

DIELECTRIC CONSTANT
TYPE 2515 CABLE
FABRICATED WITH
INTERCHEMICAL 1354
COMPOUND
DIELECTRIC CONSTANT
6.0
5.0
4.0
3.0
2.0
1.0
1.0
2.0
3.0
4.0
5.0
FREQUENCY (M.C.)

FIG 3(5)

WEIGHTED ATTENUATION

2515BI Silicone Cable

Harmonic	A^2	α	$A\alpha^2$
1	3600	.005	18
50	3470	.108	375
100	3140	.175	550
150	2640	.260	686
200	2065	.330	682
250	1454	.390	567
300	936	.455	430
350	487	.500	243
400	196	.580	113.5
450	48	.615	29.5
500	0	.690	-
550	28.6	.740	21.2
600	87.2	.800	69.8
650	139.0	.850	118.0
700	168.0	.900	151.0
750	162.0	.950	154.0
800	129.0	1.000	129.0
850	84.2	1.080	91.0
900	38.8	1.100	42.7
950	9.6	1.160	11.1
1000	0	1.200	-
1050	7.8	1.240	8.68
1100	26.0	1.300	33.80
1150	45.0	1.350	60.70
1200	56.5	1.400	79.10

Harmonic	A^2	α	$A\alpha^2$
1250	58.0	1.460	84.70
1300	49.4	1.500	74.00
1350	32.7	1.530	50.00
1400	15.6	1.590	24.80
1500	0	1.700	-
1550	3.4	1.720	5.82
1600	13.0	1.780	23.15
1650	18.4	1.820	33.50
1700	28.2	1.880	53.00
1750	30.0	1.900	57.00
1800	25.6	1.950	50.00
1850	19.0	2.000	38.00
1900	11.1	2.050	22.80
1950	2.8	2.100	5.87
2000	0	2.120	-
	19,329		5169.4

$$\frac{5169.4}{19329} = 0.267 \text{ db/100 ft.}$$

Fig. 4(5)

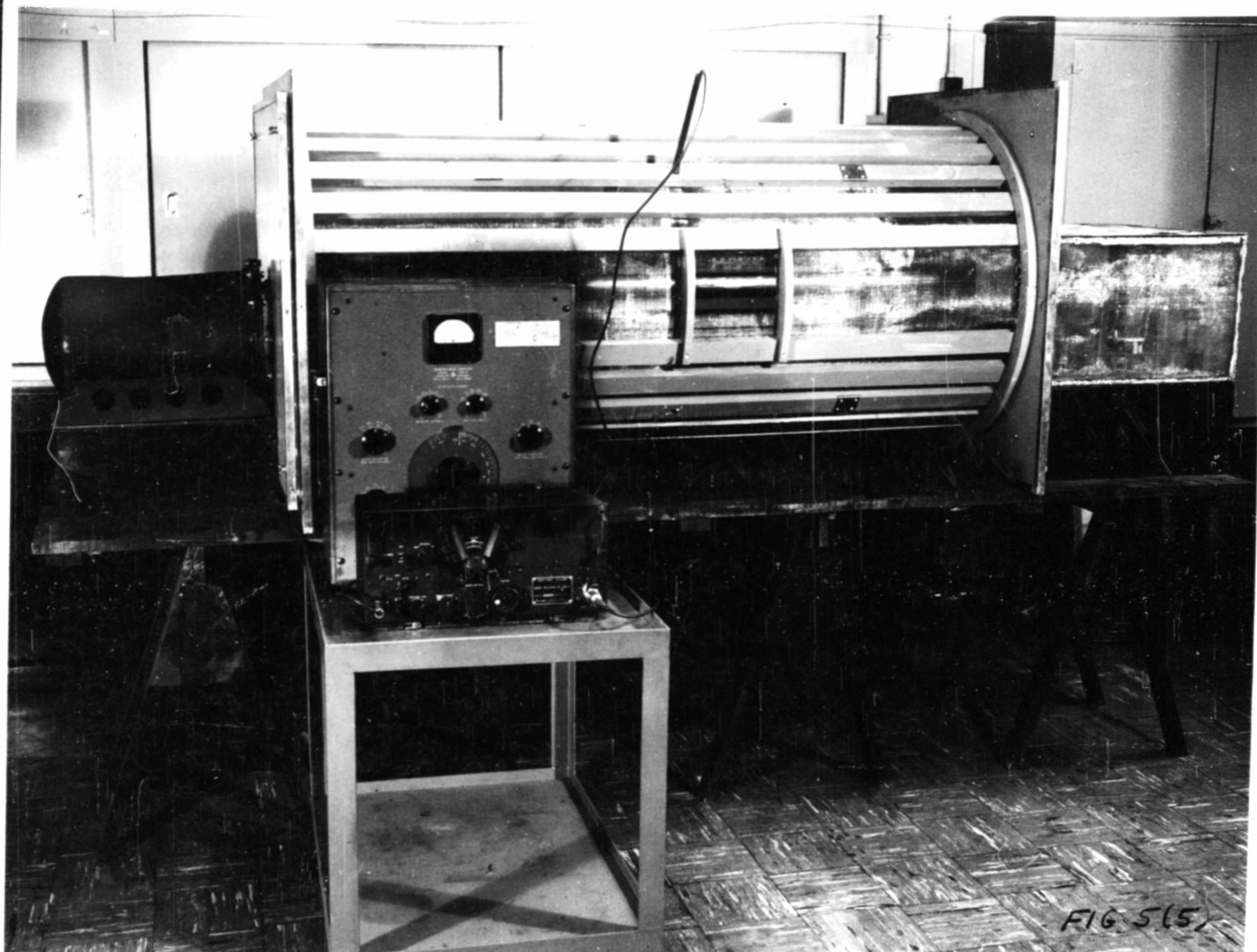
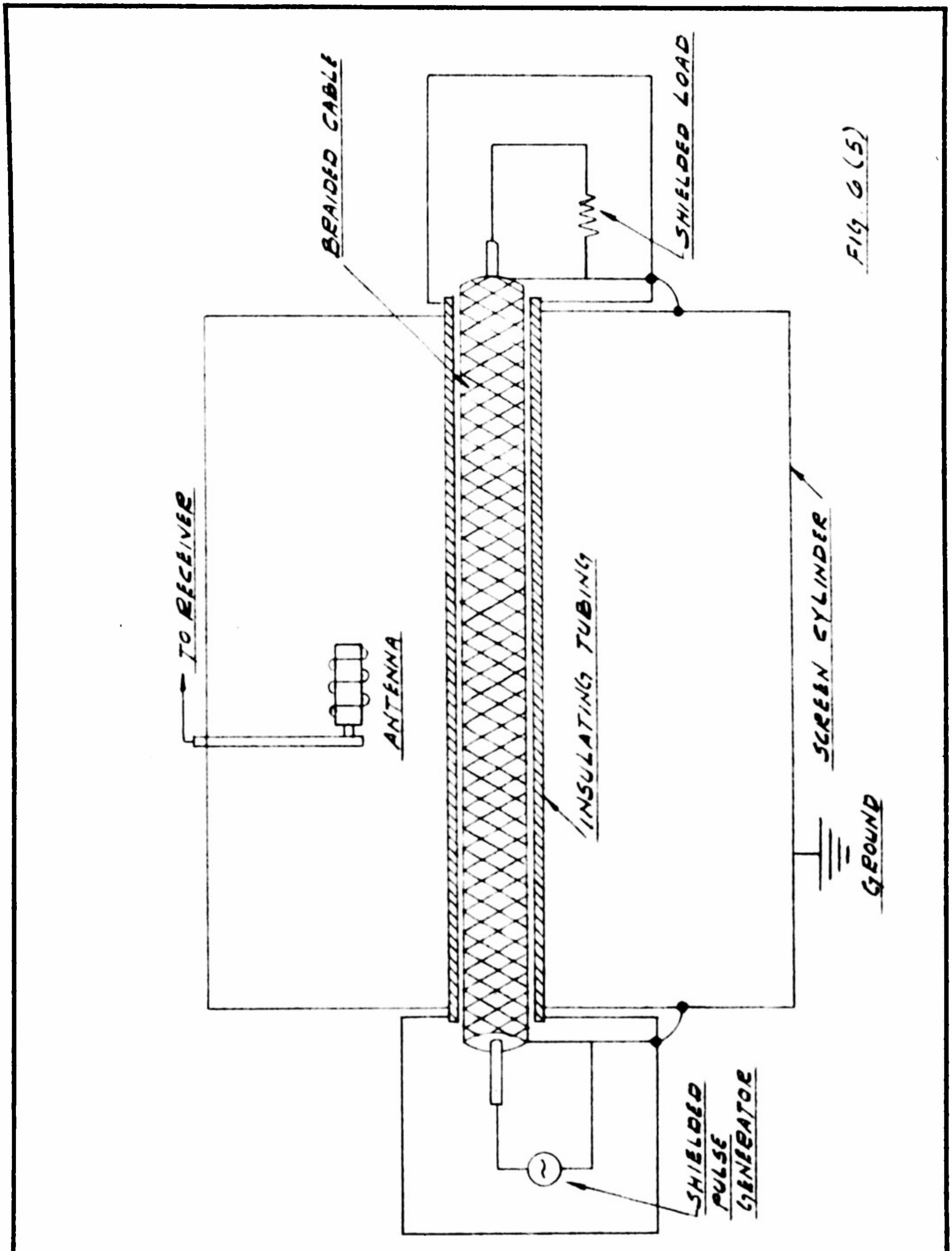


FIG. 5(5)



SHIELDING EFFECTIVENESS MEASUREMENT - CIRCUIT #1

THE OKONITE COMPANY	DATE 6-4-64	SCALE ~	REVISIONS
PASSAIC, N. J., U. S. A.	DR. B.J.W.	TR.	DRAWING NO. D-4128
	CH.	APP.	